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Englebretson, Ronald E. (LCDR, USN, Ret.) and Gilmore, Richard D. (CDR, USN, Ret.)

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This handbook for the port of Augusta Bay, one in a series of severe weather guides for Mediterranean ports, provides decision-making guidance for ship captains whose vessels are threatened by actual or forecast strong winds, high seas, restricted visibility or thunderstorms in the port vicinity. Causes and effects of such hazardous conditions are discussed. Precautionary or evasive actions are suggested for various vessel situations. The handbook is organized in four sections for ready reference: general guidance on handbook content and use; a quick-look captain's summary; a more detailed review of general information on environmental conditions; and an appendix that provides oceanographic information.

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SEVERE WEATHER GUIDE MEDITERRANEAN PORTS

4. AUGUSTA BAY

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED

CONTENTS

FOREWORD

This handbook on Mediterranean Ports was developed as part of an ongoing effort at the Naval Environmental Prediction Research Facility to create products for direct application to Fleet operations. The research was conducted in response to Commander Naval Oceanography Command (CNOC) requirements validated by the Chief of Naval Operations (CNO).

As mentioned in the preface, the Mediterranean region is unique in that several areas exist where local winds can cause dangerous operating conditions. This handbook will provide the ship's captain with assistance in making decisions regarding the disposition of his ship when heavy winds and seas are encountered or forecast at various port locations.

Readers are urged to submit comments, suggestions for changes, deletions and/or additions to NOCC, Rota with a copy to the oceanographer, COMSIXTHFLT. They will then be passed on to the Naval Environmental Prediction Research Facility for review and incorporation as appropriate. This document will be a dynamic one, changing and improving as more and better information is obtained.

M. G. SALINAS
Commander, U.S. Navy

PORT INDEX

The following is a tentative prioritized list of Mediterranean Ports to be evaluated during the five-year period 1988-92, with ports grouped by expected year of the port study's publication. This list is subject to change as dictated by circumstances and periodic review.

1988 NO.	PORT
1	GAETA, ITALY
2	NAPLES, ITALY
3	CATANIA, ITALY
4	AUGUSTA BAY, ITALY
5	CAGLIARI, ITALY
6	LA MADDALENA, ITALY
7	MARSEILLE, FRANCE
8	TOULON, FRANCE
9	VILLEFRANCHE, FRANCE
10	MALAGA, SPAIN
11	NICE, FRANCE
12	CANNES, FRANCE
13	MONACO
14	ASHDOD, ISRAEL
15	HAIFA, ISRAEL
	BARCELONA, SPAIN
	PALMA, SPAIN
	IBIZA, SPAIN
	POLLENSA BAY, SPAIN
	VALENCIA, SPAIN
	CARTAGENA, SPAIN
	GENOA, ITALY
	LIVORNO, ITALY
	SAN REMO, ITALY
	LA SPEZIA, ITALY
	VENICE, ITALY
	TRIESTE, ITALY

1989	PORT
	SPLIT, YUGOSLAVIA
	DUBROVNIK, YUGOSLAVIA
	TARANTO, ITALY
	PALERMO, ITALY
	MESSINA, ITALY
	TAORMINA, ITALY
	PORTO TORRES, ITALY

1990	PORT
	BENIDORM, SPAIN
	ROTA, SPAIN
	TANGIER, MOROCCO
	PORT SAID, EGYPT
	ALEXANDRIA, EGYPT
	ALGIERS, ALGERIA
	TUNIS, TUNISIA
	GULF HAMMAMET, TUNISIA
	GULF OF GABES, TUNISIA
	SOUDA BAY, CRETE

1991	PORT
	PIRAEUS, GREECE
	KALAMATA, GREECE
	THESSALONIKI, GREECE
	CORFU, GREECE
	KITHIRA, GREECE
	VALETTA, MALTA
	LARNACA, CYPRUS

1992	PORT
	ANTALYA, TURKEY
	ISKENDERUN, TURKEY
	IZMIR, TURKEY
	ISTANBUL, TURKEY
	GOLCUK, TURKEY
	GULF OF SOLLUM

PREFACE

Environmental phenomena such as strong winds, high waves, restrictions to visibility and thunderstorms can be hazardous to critical Fleet operations. The cause and effect of several of these phenomena are unique to the Mediterranean region and some prior knowledge of their characteristics would be helpful to ship's captains. The intent of this publication is to provide guidance to the captains for assistance in decision making.

The Mediterranean Sea region is an area where complicated topographical features influence weather patterns. Katabatic winds will flow through restricted mountain gaps or valleys and, as a result of the venturi effect, strengthen to storm intensity in a short period of time. As these winds exit and flow over port regions and coastal areas, anchored ships with large 'sail areas' may be blown aground. Also, hazardous sea state conditions are created, posing a danger for small boats ferrying personnel to and from port. At the same time, adjacent areas may be relatively calm. A glance at current weather charts may not always reveal the causes for these local effects which vary drastically from point to point.

Because of the irregular coast line and numerous islands in the Mediterranean, swell can be refracted around such barriers and come from directions which vary greatly with the wind. Anchored ships may experience winds and seas from one direction and swell from a different direction. These conditions can be extremely hazardous for tendered vessels. Moderate to heavy swell may also propagate outward in advance of a storm resulting in uncomfortable and sometimes dangerous conditions, especially during tending, refueling and boating operations.

This handbook addresses the various weather conditions, their local cause and effect and suggests some evasive action to be taken if necessary. Most of the major ports in the Mediterranean will be covered in the handbook. A priority list, established by the Sixth Fleet, exists for the port studies conducted and this list will be followed as closely as possible in terms of scheduling publications.

RECORD OF CHANGES

CHANGE NUMBER	DATE OF CHANGE	DATE ENTERED	PAGE NUMBER	ENTERED BY

1. GENERAL GUIDANCE

1.1 DESIGN

This handbook is designed to provide ship captains with a ready reference on hazardous weather and wave conditions in selected Mediterranean harbors. Section 2, the captain's summary, is an abbreviated version of section 3, the general information section intended for staff planners and meteorologists. Once section 3 has been read, it is not necessary to read section 2.

1.1.1 Objectives

The basic objective is to provide ship captains with a concise reference of hazards to ship activities that are caused by environmental conditions in various Mediterranean harbors, and to offer suggestions for precautionary and/or evasive actions. A secondary objective is to provide adequate background information on such hazards so that operational forecasters, or other interested parties, can quickly gain the local knowledge that is necessary to ensure high quality forecasts.

1.1.2 Approach

Information on harbor conditions and hazards was accumulated in the following manner:

A. A literature search for reference material was performed.

B. Cruise reports were reviewed.

C. Navy personnel with current or previous area experience were interviewed.

D. A preliminary report was developed which included questions on various local conditions in specific harbors.

E. Port/harbor visits were made by NEPRF personnel; considerable information was obtained through interviews with local pilots, tug masters, etc; and local reference material was obtained (See section 3 references).

F. The cumulative information was reviewed, combined, and condensed for harbor studies.

1.1.3 Organization

The Handbook contains two sections for each harbor. The first section summarizes harbor conditions and is intended for use as a quick reference by ship captains, navigators, inport/at sea OOD's, and other interested personnel. This section contains:

A. a brief narrative summary of environmental hazards,

B. a table display of vessel location/situation, potential environmental hazard, effect-precautionary/evasion actions, and advance indicators of potential environmental hazards,

C. local wind wave conditions, and

D. tables depicting the wave conditions resulting from propagation of deep water swell into the harbor.

The swell propagation information includes percent occurrence, average duration, and the period of maximum wave energy within height ranges of greater than 3.3 feet and greater than 6.6 feet. The details on the generation of sea and swell information are provided in Appendix A.

The second section contains additional details and background information on seasonal hazardous conditions. This section is directed to personnel who have a need for additional insights on environmental hazards and related weather events.

1.2. CONTENTS OF SPECIFIC HARBOR STUDIES

This handbook specifically addresses potential wind and wave related hazards to ships operating in various Mediterranean ports utilized by the U.S. Navy. It does not contain general purpose climatology and/or comprehensive forecast rules for weather conditions of a more benign nature.

The contents are intended for use in both pre-visit planning and in situ problem solving by either mariners or environmentalists. Potential hazards related to both weather and waves are addressed. The oceanographic information includes some rather unique information relating to deep water swell propagating into harbor shallow water areas.

Emphasis is placed on the hazards related to wind, wind waves, and the propagation of deep water swell into the harbor areas. Various vessel locations/situations are considered, including moored, nesting, anchored, arriving/departing, and small boat operations. The potential problems and suggested pre-cautionary/evasive actions for various combinations of environmental threats and vessel location/situation are provided. Local indicators of environmental hazards and possible evasion techniques are summarized for various scenarios.

CAUTIONARY NOTE: In September 1985 Hurricane Gloria raked the Norfolk, VA area while several US Navy ships were anchored on the muddy bottom of Chesapeake Bay. One important fact was revealed during this incident: Most all ships frigate size and larger dragged anchor, some more than others, in winds of over 50 knots. As winds and waves increased, ships 'fell into' the wave troughs, BROADSIDE TO THE WIND and become difficult or impossible to control.

This was a rare instance in which several ships of recent design were exposed to the same storm and much effort was put into the documentation of lessons learned. Chief among these was the suggestion to evade at sea rather than remain anchored at port whenever winds of such intensity were forecast.

2. CAPTAIN'S SUMMARY

Augusta Bay Harbor is located on the east coast of Sicily, (Figure 2-1) in the northwestern portion of the Bay of Augusta. The adjacent terrain is largely mountainous, sloping upward to over 984 ft (300 m) within 10 mi of the coast.

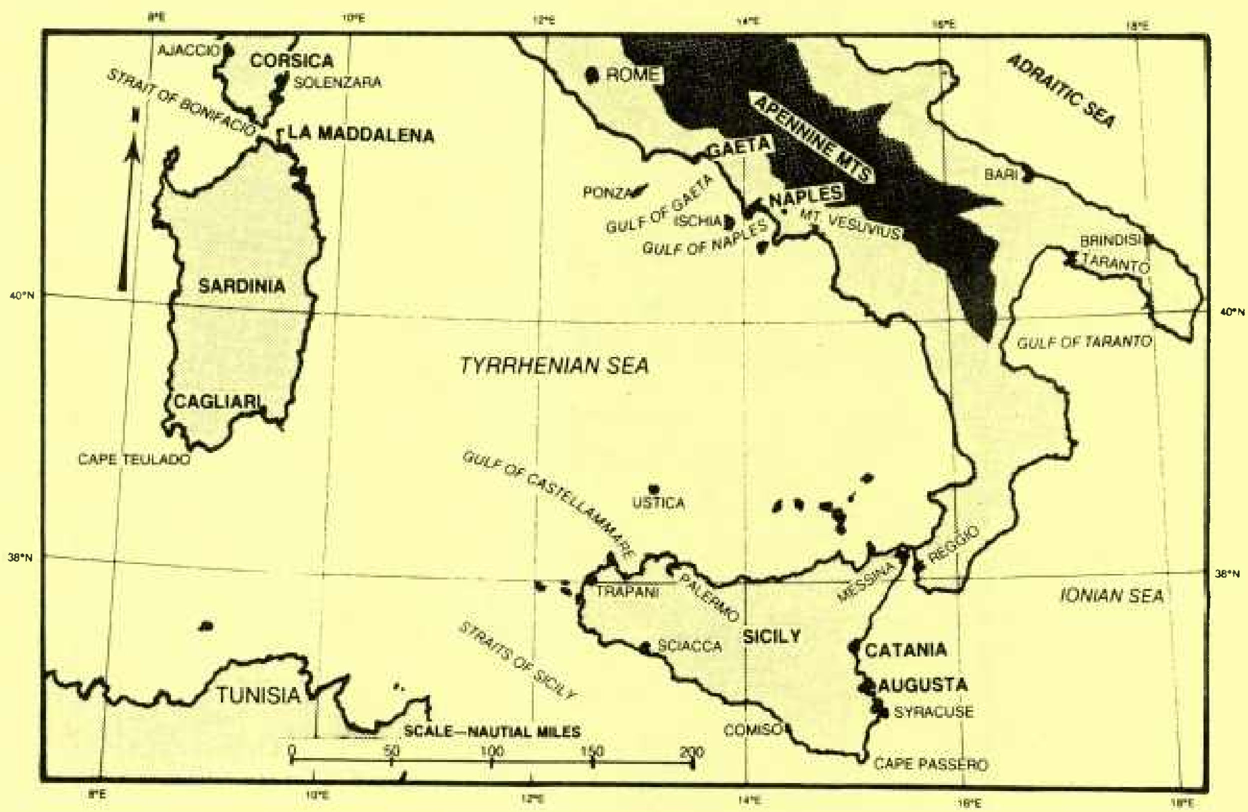

Figure 2-1. Ports of Italy, Sicily, and Sardinia.

The Bay of Augusta (Figure 2-2) is exposed to open ocean winds and waves from the eastern semi-circle. Strong offshore westerly winds affect the Bay during winter and spring.

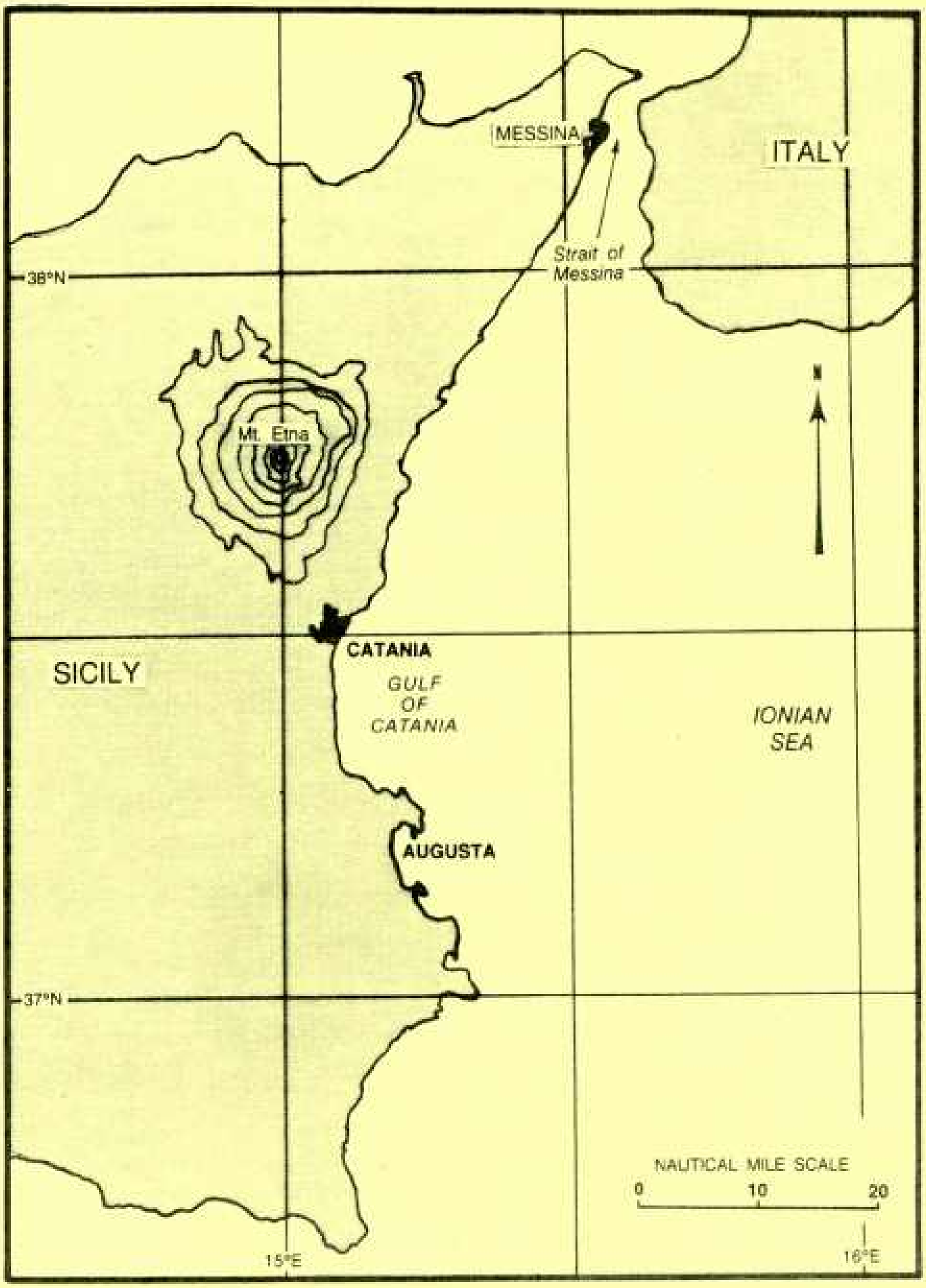

Figure 2-2. Bay of Augusta

The Port of Augusta (Figure 2-3) consists of three separate basins that comprise the Rada di Augusta (Augusta Bay): Porto Megarese, Porto Xifonio, and Seno del Priolo. Porto Megarese, having approximate dimensions of 4.4 n mi (8 km) north-south, and 2.2 n mi (4 km) east-west is the largest of the three, and the port of primary interest. Porto Xifonio and Seno del Priolo are restricted to vessels of shallow draft. Porto Xifonio, while the shallowest of the three, provides the maximum protection from winds.

Porto Megarese is bordered on the west and north by the island of Sicily. The east and south boundaries are protected by the island of Isoletto di Augusta and by three long breakwaters which are constructed on a chain of shoals which extend southward from Isoletto di Augusta. Porto Megarese is a spacious and deep harbor providing anchorage for 25-28 vessels and can accommodate ships as large as Very Large Crude Carriers (VLCC). The largest vessels of the U.S. Navy routinely entering the inner harbor are LHA's. The anchorage is limited to the central and southern portions of the harbor as the northern part is too shallow. The bottom is mud, sand, and seaweed and affords good holding except during heavy weather. Several groundings have resulted from high winds and the slick bottom mud which tends to ball up around anchor flukes and reduce their holding characteristics.

Two anchorage areas have been selected for Augusta Bay (Figure 2-3). Point 1 is just outside the primary entrance to Porto Megarese between the northern and central breakwaters. Point 2 is approximately 1 n mi south-southeast of the primary entrance and is typically used by carriers.

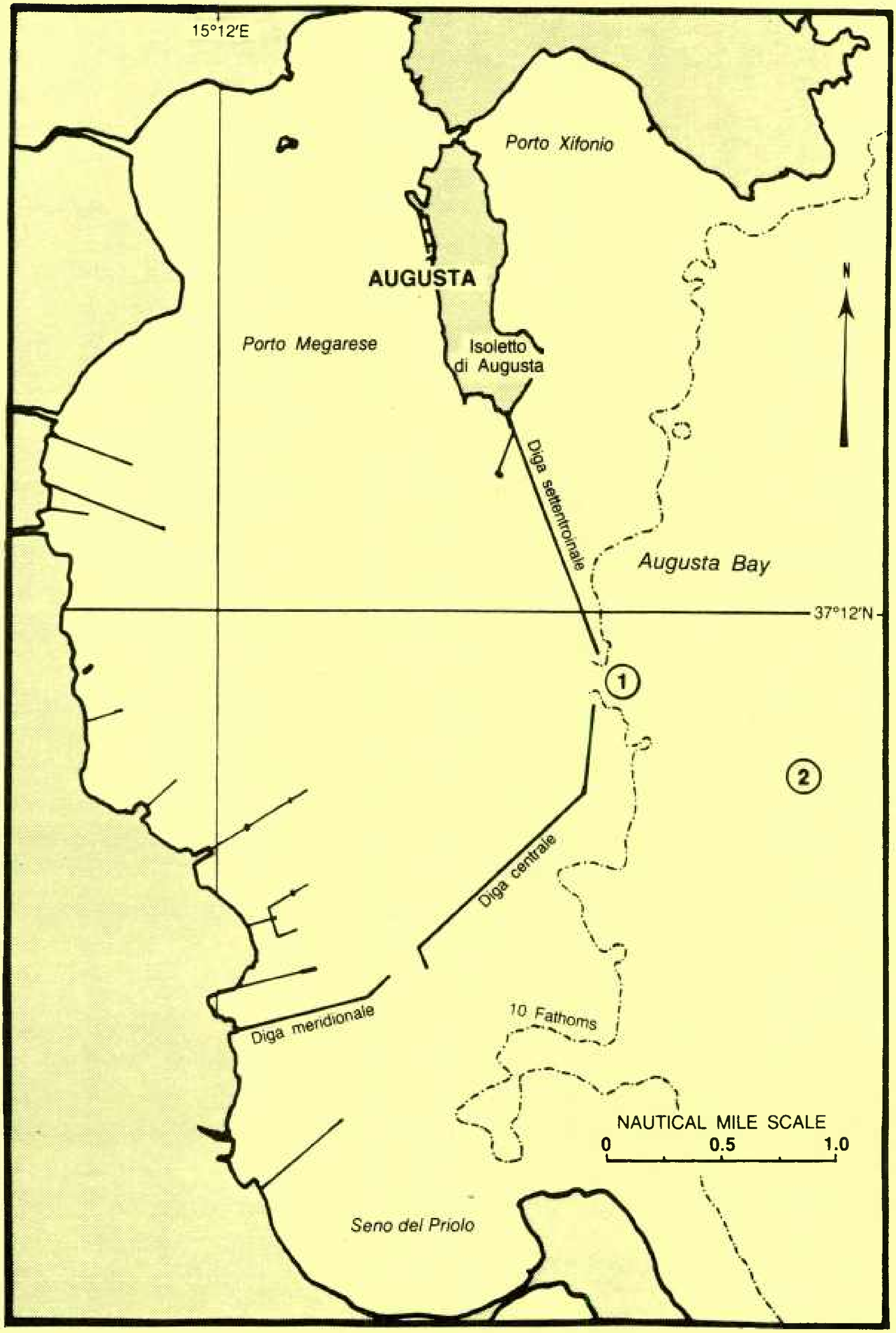

Figure 2-3. Port of Augusta

Currents in Augusta Bay are driven by the tides and wind, and can be significant when the wind is from the northeast. Generally, a south set of about 1 kt is observed 5,000 yds (2.5 n mi) from the breakwater, and a north set of about 2 kt about 2,000 yds (1 n mi) from the breakwater (U.S. Navy, 1983). Local authorities state that a clockwise current of about 1 kt is observed inside the breakwater in Porto Megarese.

According to U.S. Navy (1983), "fresh west-southwesterly winds produce a heavy sea, and may be dangerous to vessels in the roadstead." Westerly winds sometimes gust to 65 kt, and can last for 2 to 3 days in March, resulting in problems for ships anchored in mid-harbor. During winter and early spring, boating is frequently cancelled from anchorage positions in the inner and outer harbors due to westerly winds.

Anchorage can be obtained anywhere in Porto Megarese in depths of 54-90 ft (9-15 fathoms). The bottom is mostly good holding ground of mud, sand, and seaweed (Hydrographic Department, 1963). Porto Xifonio and Seno del Priolo are shallow and not considered to be safe havens for large vessels during heavy weather.

Specific hazardous environmental conditions, vessel situations, and suggested precautionary/evasion action scenarios are summarized in Table 2-1. Hazards for both inner harbor and outer harbor are addressed.

TABLE 2-1. Summary of hazardous environmental conditions for the Port of Augusta, Italy.

HAZARDOUS CONDITION	INDICATORS OF POTENTIAL HAZARD	VESSEL LOCATION/ SITUATION AFFECTED	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS
1. Wind a. Easterly winds - Strong winds from NE through SE. May be called Gregale, Levante, or Scirocco. * Strongest and most frequent in winter. * Can produce sea/swell to 23-26 ft (7-8 m) in outer harbor. * May be accompanied by thunderstorms if caused by transient low south of Sicily.	Advance warning. * Transient low pressure system south of Sicily. * Building high pressure over Europe coincident with development of low over North Africa or Ionian Sea. * Scirocco event may be preceded by cumulus clouds building and remaining over Mount Etna when air flow is from SE. Duration * Transient low pressure system south of Sicily can cause winds to last for 1-2 days. * Building high over Europe with low over North Africa or Ionian Sea can produce winds lasting 5 days. * Scirocco events can last 2 weeks.	(1) Anchored - inner harbor - outer harbor (2) Moored - inner harbor (3) Arriving/departing harbor (4) Small boat operations	THE PORT OF AUGUSTA OFFERS NO PROTECTION FROM WIND. (a) Anchor may drag in strong winds. * Mud tends to ball up around anchor flukes and decrease holding characteristics. * Best to depart harbor if high wind situation is forecast. * If remaining at anchor and strong winds are forecast, use of two anchors is recommended. (b) Small craft * Extra securing precautions required. (a) Wind may force ship off its mooring * Mooring lines should be doubled. * Tug assistance may be necessary in strong event. * If nested, vessels may shift depending on wind direction. (a) Strong winds may prevent/hamper ship movement in/out of harbor. * Pilot boat may not leave harbor in strong E'ly wind/sea. (a) Boating may be restricted. * Small boat operations may be cancelled/restricted in high wind situation.
b. Westerly winds - Strong winds from SW through NW. May be called Libeccio, Ponente, or Maestrale. * Strongest in March (usually 18th/19th). * Sustained speeds of 35 kts or higher with gusts to 65 kts not uncommon.	Advance warning * Strong low pressure system development north of Sicily. Duration * May last 2-3 days in March.	(1) Anchored - inner harbor - outer harbor (2) Moored - inner harbor (3) Arriving/departing harbor (4) Small boat operations	(a) Anchor may drag in strong winds. * Ponente (NW) winds in March are worst for ships in inner harbor anchorage. * Mud tends to ball up around anchor flukes and decrease holding characteristics. * Best to depart harbor if high wind situation is forecast. * If remaining at anchor and strong winds are forecast, use of two anchors is recommended. (b) Small craft * Extra securing precautions required. (a) Wind may force ship off its mooring * Mooring lines should be doubled. * Tug assistance may be necessary in strong event. * If nested, vessels may shift depending on wind direction. (a) Ship movement in/out of harbor may be hampered/restricted (a) Boating may be restricted. * Small boat operations may be cancelled/restricted in high wind situation.
c. Sea breeze - Diurnal on-shore wind reaching maximum velocity in mid-afternoon. * Most common in summer, but may occur on warm days in spring and autumn. * Commonly observed between 1030L and 1800L, reaching maximum velocities about 1530L. * Normal velocity range is 10-20 kts but strong event can exceed 27 kts.	Advance warning * Routinely observed in summer and on warm late spring and early autumn days. Duration * Typically observed between 1030L and 1800L.	(1) Anchored - inner harbor (2) Anchored - outer harbor (3) Moored - inner harbor (4) Arriving/departing harbor (5) Small boat operations	(a) No significant problems. (a) No significant problems. (a) No significant problems. (a) Vessel control may be affected at slow SOA. (a) Small boating may be hampered or curtailed in a strong event.

TABLE 2-1. (Continued)

HAZARDOUS CONDITION	INDICATORS OF POTENTIAL HAZARD	VESSEL LOCATION/ SITUATION AFFECTED	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS
2. Easterly sea/swell - Waves resulting from easterly winds discussed in 1.a above plus swell generated by Etesian winds over Aegean Sea during summer (maximum occurrence in August) and propagated westward to Sicily. * Strong Gregale can produce 23-26 ft (7-8 m) seas in outer harbor. * Swell from Etesian winds may reach 8-12 ft (2.5-3.5 m) in outer harbor. * Seas rarely exceed 2-3 ft in inner harbor.	Advance warning * Easterly moving system south of Sicily. * Developing high over Europe and low over N. Africa. * Scirocco event may be preceded by cumulus couds building over and remaining over Mount Etna when air flow is from SE. * Swell from Etesian winds can be expected when summer monsoon established. Maximum occurrence is in August. * Swell may be anticipated at Augusta Bay 4-8 hours after strong Etesian winds commence over Aegean Sea. Duration * Waves generated by local wind (only) will diminish rapidly with decrease in wind. * Swell waves diminish slowly after winds at source subside, with heights and periods decreasing over time.	(1) Anchored - inner harbor (2) Anchored - outer harbor (3) Moored - inner harbor (4) Arriving/departing harbor (5) Small boat operations	(a) Little effect in inner harbor. (a) Vessels may have to depart anchorage. * Large swell waves may cause significant pitching at anchor. * Anchor dragging may result from swell motion, or combination of waves and wind (if present). * Proceeding N through Strait of Messina to anchorages at Palermo or Gulf of Castellammare on N coast of Sicily will avoid swell. * Steaming close to W coast of Italian Peninsula will avoid swell. (a) No significant problems. (a) Swell at harbor entrance and in outer harbor may pose hazards to vessels entering or leaving port * Limited maneuvering room available. * Harbor pilot availability may be impacted if swell is accompanied by strong winds. (a) Outer harbor operations may be restricted/cancelled. * Large swell may prevent small boats from safely coming alongside. * Small boating may be cancelled if swell is accompanied by strong winds.
3. Thunderstorm - May occur independent of or imbedded in extensive rain area, and in association with passing frontal systems. * Commonly occurs in autumn/early winter as part of larger rain area. May last more or less continuously for 24 hrs. * May occur with passing frontal systems. * May be accompanied by strong winds.	Advance warning * Rain forecast in autumn or early winter due to low pressure system passing south of Sicily. * Strong frontal passage during autumn, winter, or spring. Duration * Can last for 24 hours when associated with transient low south of Sicily in late autumn or early winter.	(1) Anchored - inner harbor - outer harbor (2) Moored - inner harbor (3) Arriving/departing harbor (4) Small boat operations	(a) Possible strong winds/squalls/lightning strikes. * Personnel should be alert for anchor dragging. * Secure loose gear. * Minimize personnel exposure on weather decks. (a) Possible strong winds/squalls/lightning strikes * Mooring lines should be monitored closely. * Secure loose gear. * Minimize personnel exposure on weather decks. (a) Possible strong winds/squalls/lightning strikes * Ship maneuvering may be affected. * Visibility may be restricted. * Secure loose gear. * Minimize personnel exposure on weather decks. (a) Small boat operations should be restricted. * Wind gusts/squalls may hazard small boats and occupants. * Lightning strikes are possible.
4. Tropical cyclone - Although uncommon, tropical cyclones have been observed in the Mediterranean basin. * Most likely in late summer/ autumn,but may occur in any season. * Storm track is difficult to forecast accurately. Mariners must give wide berth to forecast track. * Damage can be caused by winds and/or high water caused by storm surge.	Advance warning * High, thin clouds in cyclonically spiralling bands, gradually thickening. * Long period swell from southern semicircle with no other reasonable explanation.	(1) Anchored - inner harbor (2) Anchored - outer harbor (3) Moored - inner harbor (4) Arriving/departing harbor (5) Small boat operations	(a) Vessels should put to sea and evade storm. (a) Vessels should put to sea and evade storm. (a) Vessels should put to sea and evade storm. (a) Vessels should put to sea and evade storm. * If at sea, stay at sea and evade storm. * If departing harbor, plan to leave early to avoid effects of storm. (a) Cancel small boat operations. * Hoist small craft out of water and secure on deck or, if on shore, well above high tide line.

Table 2-2 provides the height ratio and direction of shallow water waves to expect at points 1 and 2 (Figure 2-3) when the deep water wave conditions are known.

The Augusta Bay Point 2 conditions are found by entering Table 2-2 with the forecast or known deep water wave direction and period. The height is determined by multiplying the example deep water wave height (8 ft) by the ratio of shallow to deep height (.6).

Example: Use of Table 2-2 for Augusta Bay Point 2.

Deep water wave forecast as provided by a forecast center or a reported/observed deep water wave condition:

8 feet, 12 seconds, from 180°.

The expected wave condition at Augusta Bay Point 2 as determined from Table 2-2:

4-5 feet, 12 seconds, from 165°.

NOTE: Wave periods are a conservative property and remain constant when waves move from deep to shallow water, but speed, height, and steepness change.

Table 2-2. Shallow water wave directions and relative height conditions versus deep water period and direction (see Figure 2-3 for location of points).

FORMAT: Shallow Water Direction
Wave Height Ratio: (Shallow Water/Deep Water)

AUGUSTA BAY POINT 1:

Period (sec)	6	8	10	12	14	16
Deep Water Direction	Shallow Water Direction and Height Ratio					
360°	020°	025°	030°	040°	050°	050°
	.3	.3	.4	.3	.3	.3
030°	045°	060°	040°	045°	050°	060°
	.3	.3	.6	.5	.8	.7
060°	060°	060°	060°	060°	065°	065°
	.9	.9	.8	.6	.5	.6
090°	090°	090°	085°	085°	085°	085°
	.9	.9	.8	.8	.6	.6
120°	120°	115°	110°	110°	105°	100°
	.8	.7	.7	.6	.7	.6
150°	135°	140°	120°	130°	120°	110°
	.6	.6	.6	.6	.5	.5
180°	165°	160°	155°	140°	130°	115°
	.6	.3	.2	.5	.5	.3

AUGUSTA BAY POINT 2:

Period (sec)	6	8	10	12	14	16
Deep Water Direction	Shallow Water Direction and Height Ratio					
360°	005°	010°	015°	020°	030°	030°
	.4	.6	.7	.8	.5	.4
030°	030°	030°	030°	035°	045°	055°
	1.0	.9	.8	.7	.6	.5
060°	060°	060°	060°	060°	065°	065°
	1.0	1.0	.9	.9	.9	.9
090°	090°	090°	090°	090°	090°	090°
	1.0	1.0	.9	.9	.8	.8
120°	120°	120°	120°	120°	115°	115°
	1.0	.9	.9	.9	.8	.7
150°	150°	150°	150°	145°	145°	140°
	.9	.9	.9	.8	.8	.8
180°	180°	175°	170°	165°	160°	150°
	.6	.5	.6	.6	.6	.6

The local wind generated wave conditions for the anchorage area identified as point 2 (Figure 2-3) are given in Table 2-3. All heights refer to the significant wave height (average of the highest 1/3 waves). Enter the local wind speed and direction in this table to obtain the minimum duration in hours required to develop the indicated fetch limited sea height and period. The time to reach fetch limited height is based on an initial flat ocean. When starting from a pre-existing wave height, the time to fetch limited height will be shorter.

Table 2-3. Augusta Bay near point 2. Local wind waves for fetch limited conditions related to point 2 (based on JONSWAP model).

Format: height (feet)/period (seconds)
time (hours) to reach fetch limited height

Direction and\ Fetch \ Length \ (n mi)	Local Wind Speed (kt) 18	24	30	36	42
SW 3 n mi	<2 ft	<2 ft	2/3 1	2/3 1	2-3/3 1
S 5 n mi	<2 ft	2/3 1	2-3/3-4 1	3/3-4 1	3-4/4 1

Example:
To the SW (225°) there is about a 3 n mi fetch (Figure 2-3). Given a SW wind at 30 kt, the sea will have reached 2 feet with a period of 3 seconds within 1 hour. Wind waves will not grow beyond this condition unless the wind speed increases or the direction changes to one over a longer fetch length. If the wind waves are superimposed on deep water swell, the combined height may change in response to changing swell conditions. Wind wave directions are assumed to be the same as the wind direction.

Combined Wave heights are obtained by finding the square root of the sum of the squares of the swell and wind wave heights.

Example: Swell 10 ft, wind wave 5 ft.

$$\sqrt{10^2 + 5^2} = \sqrt{100 + 25} = \sqrt{125} \approx 11.2 \text{ ft}$$

Note: Increase over larger height is small. If both heights were equal, combined height would increase by a factor of 1.4. If one is half of the other, as in the example, increase over the larger of the two is by a factor of 1.12.

Climatological factors of shallow water waves, as described by percent occurrence, average duration, and period of maximum energy (period at which the most energy is focused for a given height), are given in Table 2-4. See Appendix A for discussion of wave spectrum and energy distribution. These data are provided by season for two ranges of heights: greater than 3.3 and greater than 6.6 feet for the two anchorage areas indicated on Figure 2-3.

Table 2-4. Shallow water climatology as determined from deep water wave propagation. Percent occurrence, average duration or persistence, and wave period of maximum energy for wave height ranges of greater than 3.3 feet and greater than 6.6 feet by climatological season.

AUGUSTA POINT 1:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	30	29	8	20
Average Duration (hrs)	14	17	11	16
Period Max Energy (sec)	10	10	10	8
>6.6 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	13	10	2	5
Average Duration (hrs)	14	11	8	8
Period Max Energy (sec)	12	11	10	10

AUGUSTA POINT 2:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	29	22	9	15
Average Duration (hrs)	13	11	15	14
Period Max Energy (sec)	10	10	10	10
>6.6 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	12	9	2	6
Average Duration (hrs)	10	14	11	7
Period Max Energy (sec)	12	11	10	12

SEASONAL SUMMARY OF HAZARDOUS WEATHER CONDITIONS

WINTER (November thru February):

* Strong east or east-northeast winds (Gregale).
* Strong southeast winds (Scirocco).
* Westerly winds (Poniente) with gusts to 65 kt.
* Gregale and Scirocco can cause high waves at anchorage.
* Thunderstorms occur with frontal passages and can last for 24 hours bringing heavy rain and hail.

SPRING (March thru May):

* Early spring similar to winter, especially for Poniente.
* Thunderstorms occur less but still a threat.
* Sea breeze occurs occasionally, rarely disrupts boating.

SUMMER (June thru September):

* Sea breeze daily occurrence, peaking at 1530L, occasionally postponing boating operations.
* Etesian wind over eastern Mediterranean can bring 12 ft (4 m) swell to anchorage areas.

AUTUMN (October):

* Short transition season with winter weather returning by end of month.

NOTE: For more detailed information on hazardous weather conditions see previous Summary Table in this section and Hazardous Weather Summary in Section 3.

REFERENCES

U. S. Navy, 1983: Fleet Directory for Augusta, Sicily, Italy (FOUO).

3. GENERAL INFORMATION

This section expands on the material in the Captain's Summary. Figures and Tables are repeated with a continuation of numbering. Paragraph 3.5 provides a general discussion of hazards and Table 3-4 provides a summary of hazards and actions by season.

3.1 Geographic location

The Port of Augusta is located at 37°13'N 15°14'E on the east coast of the Italian island of Sicily (Figure 3-1).

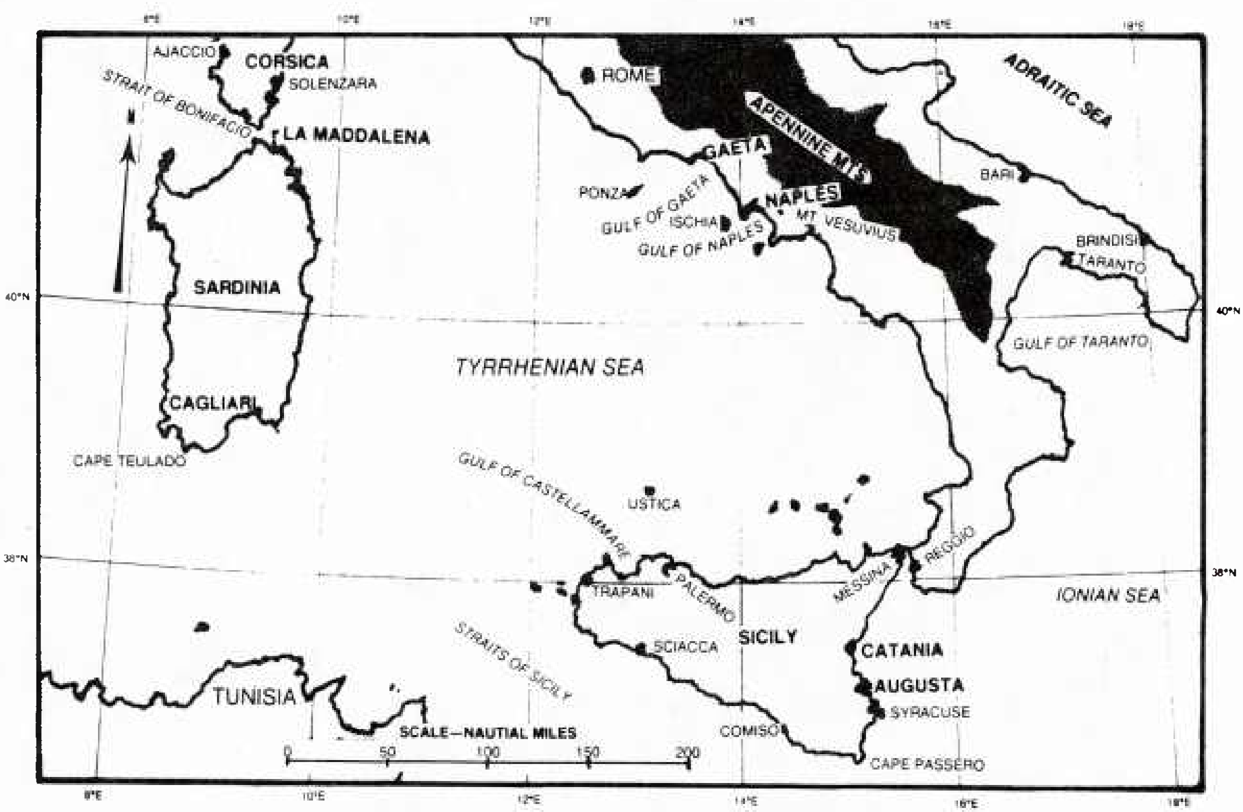

Figure 3-1. Ports of Italy, Sicily, and Sardinia.

The Bay of Augusta (Figure 3-2) is exposed to open ocean winds and waves from the eastern semi-circle. Strong offshore westerly winds affect the Bay during winter and spring.

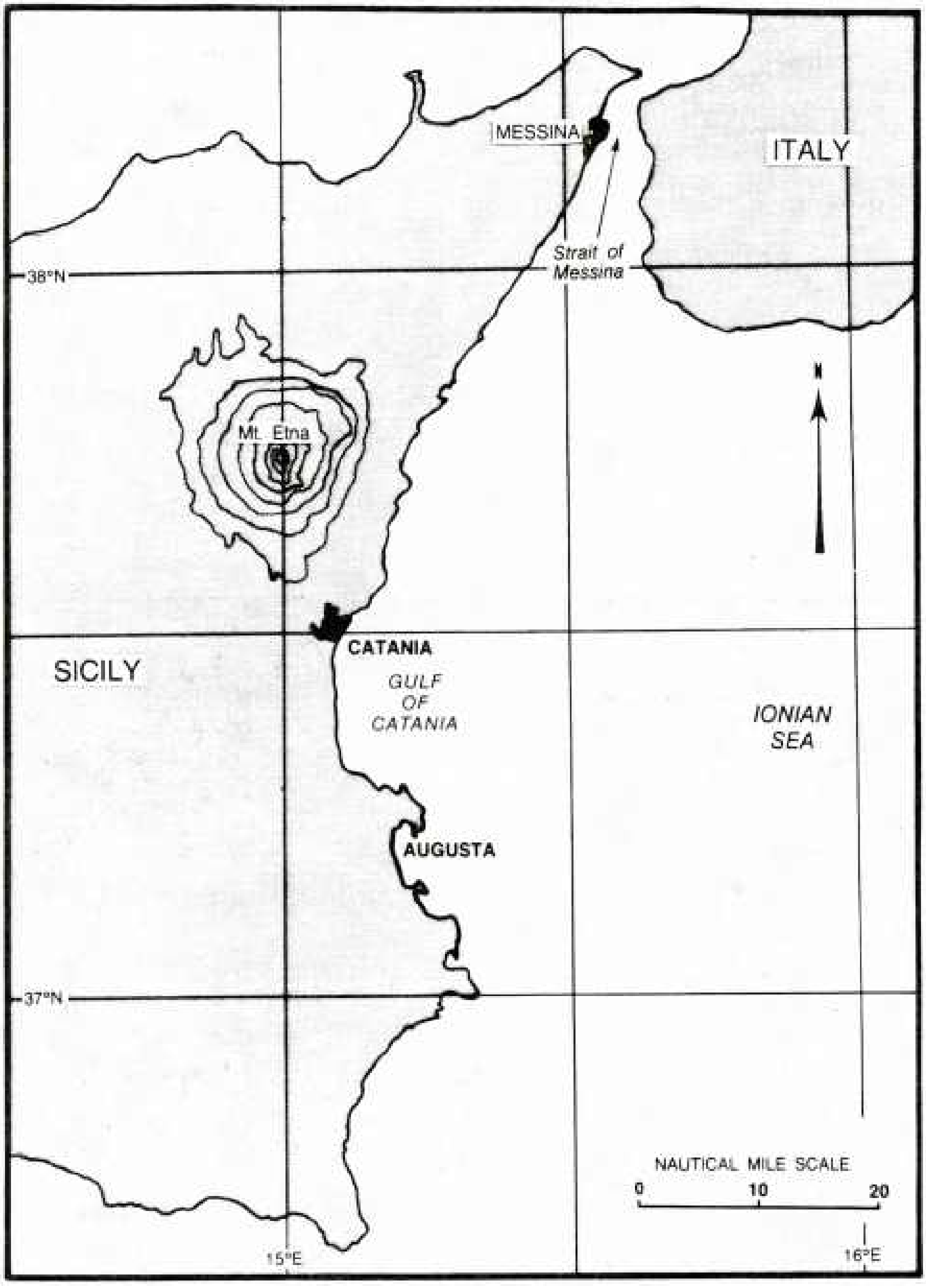

Figure 3-2. Bay of Augusta

The Port of Augusta facilities are situated in three of the basins that comprise Rada di Augusta (Augusta Bay): Porto Megarese, Porto Xifonio, and Seno del Priolo (Figure 3-3). Porto Megarese, a natural harbor having approximate dimensions of 4.4 n mi (8 km) north-south, and 2.2 n mi (4 km) east-west, is the largest of the three and the port of primary interest. The island of Sicily forms its western and northern boundaries, and its eastern and southern boundaries are comprised of Isoletto di Augusta, an elongated island on which the municipality of Augusta is located, and three extensive breakwaters: Diga settentrionale (northern levee), Diga centrale (central levee), and Diga meridionale (southern levee). The primary entrance to Porto Megarese passes between the northern and central breakwaters, with a width of 1,200 ft (366 m), and channel depth of 42 ft (13 m) or greater.

Porto Megarese is a spacious and deep harbor which can accomodate ships as large as 250,000 DWT. The Fleet Directory for Augusta, Sicily, Italy published by the U.S. Navy (1983), states that anchorage is available inside the breakwaters in the "central zone", with water depths not less than 73.5 ft (22.4 m). LHA's are the largest vessels of the U.S. Navy routinely entering the inner harbor. Shallow water depths in the northern part of the harbor restrict its use. Porto Xifonio and Seno del Priolo offer protected anchorages to small vessels only.

The terrain of Sicily adjacent to Augusta Bay is largely mountainous. Elevations within 10 mi of Augusta Bay range from sea level along the coast sloping upward to over 984 ft (300 m), with one peak reaching 1,870 ft (570 m). Mt. Etna, a 10,902 ft (3,323 m) active volcano, is the highest point on Sicily and is located about 35 n mi north-northwest of the port.

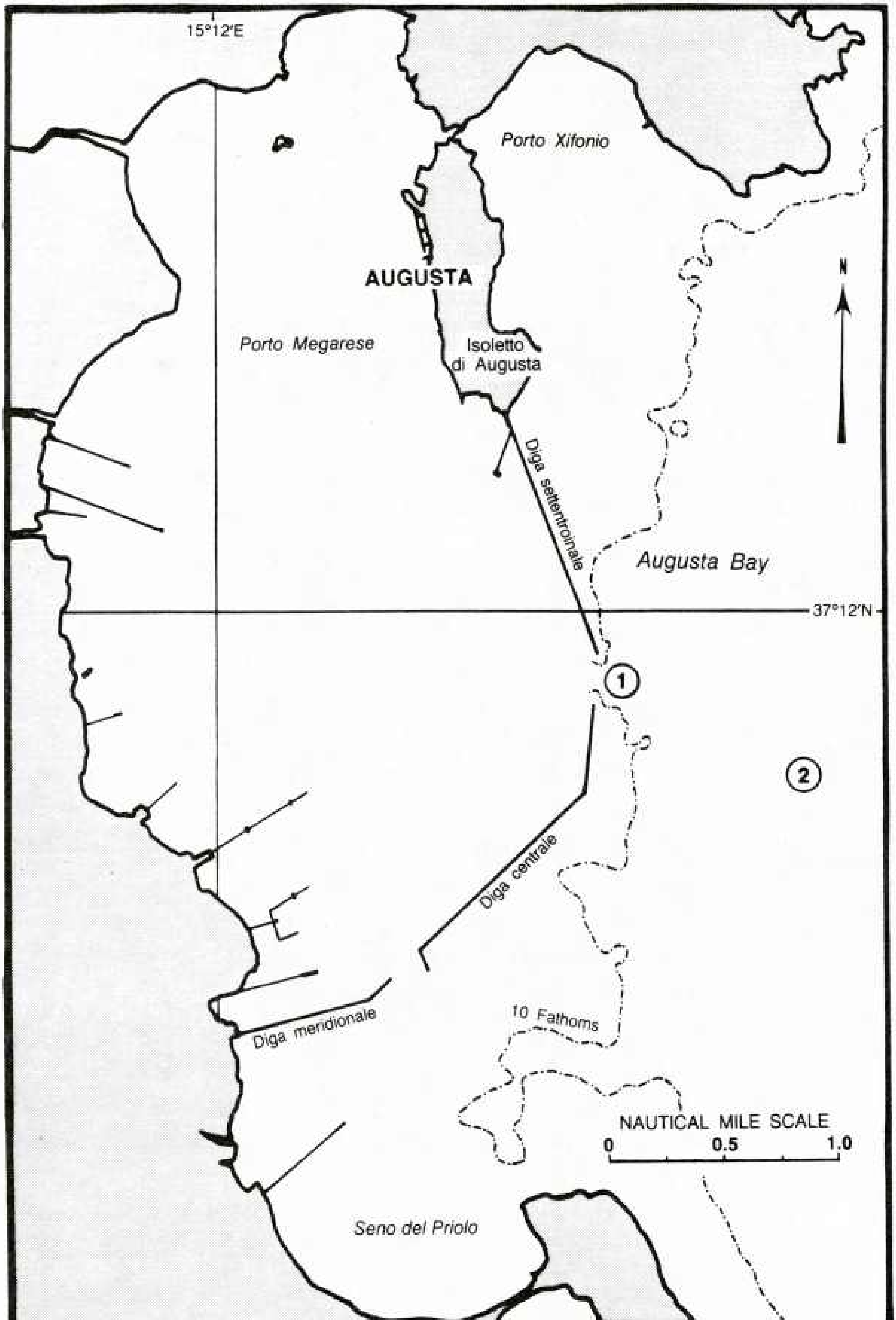

Figure 3-3. Port of Augusta

3.2 Qualitative Evaluation of the Port of Augusta

The Port of Augusta is fairly well protected from hazardous seas by its periphery of breakwaters. Heavy seas, which may reach 23-26 ft (7-8 m) in height in the outer harbor, break rather heavily over the breakwaters but only slight seas result in the inner harbor. Caution is necessary when approaching the harbor in bad weather because of the breaking seas (Hydrographic Department, 1963). At times, the harbor pilots will not leave the inner harbor because of high winds and heavy seas outside the harbor entrance. Local harbor authorities advise that when high northeast to southeast winds are forecast, it is best to leave the port and head for open sea.

According to U.S. Navy (1983), "fresh west-southwesterly winds produce a heavy sea, and may be dangerous to vessels in the roadstead." Westerly winds sometimes gust to 65 kt, and can last for 2 to 3 days in March, resulting in problems for ships anchored in mid-harbor. During winter and early spring, boating is frequently cancelled from anchorage positions in the inner and outer harbors due to westerly winds.

Anchorage can be obtained anywhere in Porto Megarese in depths of 54-90 ft (9-15 fathoms). The bottom is mostly good holding ground of mud, sand, and seaweed (Hydrographic Department, 1963). Porto Xifonio and Seno del Priolo are shallow and not considered to be safe havens for large vessels during heavy weather.

3.3 Currents and Tides

Currents are driven by the tides and wind, and can be significant when the wind is from the northeast. Generally, a south set of about 1 kt is observed 5,000 yds (2.5 n mi) from the breakwater, and a north set of about 2 kt about 2,000 yds (1 n mi) from the breakwater

(U.S. Navy, 1983). Harbor pilots say that a clockwise current of about 1 kt is observed inside the breakwater at Porto Megarese.

3.4 Visibility

Reduced visibility is rarely a problem at Augusta Bay. Morning haze and fog create the poorest conditions, but dissipate rapidly during morning hours.

3.5 Hazardous Conditions

Although relatively protected from hazardous sea conditions, the Port of Augusta is vulnerable to the effects of high winds. A seasonal summary of the various known environmental hazards that may be encountered in the Port of Augusta follows.

A. Winter (November through February)

Strong winds from the eastern quadrant (northeast through southeast) can cause significant problems in Augusta Bay. Although the inner harbor is protected from the full impact of the sea generated by the winds, the force of the wind can adversely impact small boating operations in the inner harbor. The wind can cause ships in the anchorages to drag anchor, while the combined effects of wind and sea can impact the ability of harbor pilots to leave port to meet incoming vessels. Experienced mariners advise that when strong winds from the east quadrant are forecast for Augusta Bay, it is best to leave the port and head for open sea. A primary cause of such wind during the winter is the "Gregale". It occurs with high pressure over central Europe or the Balkans and low pressure over the Ionian Sea or Tunisia/Libya and may continue for up to 5 days. It can also occur with the passage of a depression to the south or southeast, when it lasts only a day or two. Gregale winds can be reinforced by flow through the Strait of Messina.

Strong southeasterly winds can be caused by a "Scirocco". A low pressure center over North Africa

brings east to southeast winds to Augusta Bay, accompanied by low stratus and fog. A Scirocco event will bring hot and muggy weather to the area and may last up to 2 weeks, with one recorded occurrence persisting for one month.

Strong winds from the western quadrant , locally known as "Ponente" and resulting from a low pressure system north of the area, can be a problem for ships anchored in the inner harbor due to anchor dragging. Boating is frequently cancelled from anchorage positions in the inner and outer harbors. Westerly winds with gusts to 65 kt have been observed at Augusta Bay.

Heavy rain with low cloud ceilings can occur at Augusta Bay when a low pressure system passes south of Sicily. Thunderstorms, commonly associated with the aforementioned low passages in early winter when SST's are still warm but air temperatures may be cool, may be constant for 24 hours. Thunderstorms may also occur with passing frontal systems.

B. Spring (March through May)

Early spring environmental conditions are similar to those of winter. Winds and seas from the northeast through southeast continue to affect harbor operations at Augusta Bay. Strong westerly winds, known as Ponente, with gusts to 65 kt are most prevalent in March, and have been known to last for 2-3 days. Ponente winds cause significant problems in the harbor due to anchor dragging.

Although most common during summer, sea breezes start to appear in late spring. A strong event can reach 25 kt, which may affect boating in the harbor.

Rain is common when low pressure systems pass south of Sicily, but because of cooler SST's, associated thunderstorm activity is not as evident as in early winter.

Although not as common as during the winter, Scirocco conditions are occasionally observed during spring, primarily early in the season. A Scirocco event may bring strong east to southeast winds accompanied by

low stratus and fog to Augusta Bay. Sciroccos may last up to two weeks and bring hot and muggy weather to the area.

C. Summer (June through September)

The summer season in eastern Sicily has the least hazardous weather of the year. The track of strong extratropical storms has moved northward and poses little threat to Augusta Bay. Sea breezes are daily occurrences, usually commencing about 1030L, reaching maximum strength of about 15 kt by 1530L, and diminishing by 1800L. A strong event may reach 25 kt. A high pressure cell aloft can suppress the sea breeze flow; the sea breeze usually overcomes the resistance but is not as strong as usual.

The prevailing northern winds over the eastern Mediterranean and Aegean Seas during the summer (basically a monsoonal flow associated with a deep low pressure area which forms over northwest India) is called the "Etesian." Once established, it can generate a 8-12 ft (2.5-3.5 m) westerly moving swell which will reach the east coast of Sicily in 4-8 hours. The maximum occurrence of Etesian winds and resultant swell is in August. Due to the protective breakwaters around the inner harbor, the impact of the swell is limited to the outer harbor of Augusta Bay.

D. Autumn (October)

The autumn season is short, with the typical season usually spanning about one month -- October. The daily occurrence of the sea breeze is interrupted as temperatures begin to moderate. Extratropical systems begin to transit Europe as the storm track moves southward in advance of the winter season.

The threat of strong winds from the eastern quadrant caused by a Gregale or Scirocco, as discussed in section A above, increases as the autumn season progresses. Strong westerly winds, also addressed in section A above, become more common as extratropical systems transit the waters north of Sicily.

Heavy rain with low cloud ceilings can occur at Augusta Bay when a low pressure system passes south of Sicily. Thunderstorms, commonly associated with the aforementioned low passages in late autumn when SST's are still warm but air temperatures may be cool, may be constant for 24 hours. Thunderstorms may also occur with passing frontal systems late in the season.

E. Tropical Storm Season

Storms having tropical cyclone characteristics with fully developed eyes have been observed on at least three occasions in the Mediterranean basin: 23-26 September 1969, 22-28 January 1982, and 26-30 September 1983. On the latter occasion the storm moved northwest from the Gulf of Gabes (on the southeast coast of Tunisia), through the Strait of Sicily, along the east coast of Sardinia, and into the Gulf of Genoa. Winds of 100 kt were observed near the eye while Cagliari, Sardinia reported sustained winds of 60 kt. The potential for a storm of this type to strike Augusta Bay is real and the meteorologist must be aware of the possibility.

3.6 Harbor Protection

The Port of Augusta offers little protection from wind but the inner harbor, as detailed below, provides good protection from significant wave action.

3.6.1 Wind and Weather

The Port of Augusta is unprotected from the full force of wind from northeast clockwise through south-southeast. From south-southeast clockwise through northeast, the topography of Sicily affords only rather limited protection; the highest point of the terrain within 20 mi of the port is 3,655 ft (1,114 m), with most elevations considerably less.

3.6.2 Waves

The harbor of Porto Megarese is afforded excellent protection from waves that have been generated in the open sea by the configuration of Isolotto di Augusta and the three breakwaters which form the east and southeast limits of the inner harbor. While waves from the east or southeast may break over the top of the breakwaters, the impact on inner harbor operations is minimal. Limited wave energy can enter the inner harbor through the main entrance between Diga settentrionale and Diga centrale, but due to the relatively narrow entrance the effects are minimal on the inner harbor operations.

The outer harbor is exposed to the full force of waves emanating from northeast through south-southeast and it will be advisable to sortie under high wind/wave conditions.

Table 3-1 provides the shallow water wave conditions at the two designated points when deep water swell enters the Bay of Augusta.

Example: Use of Table 3-1.
For a deep water wave condition of:
6 feet, 12 seconds, from 120°
The approximate shallow water wave conditions are:
Point 1: 4 feet, 12 seconds, from 110°
Point 2: 5-6 feet, 12 seconds, from 120°

Table 3-1. Shallow water wave directions and relative height conditions versus deep water period and direction (see Figure 3-3 for location of points).

FORMAT: Shallow Water Direction
Wave Height Ratio: (Shallow Water/Deep Water)

AUGUSTA BAY POINT 1:

Period (sec)	6	8	10	12	14	16
Deep Water Direction	Shallow Water Direction and Height Ratio					
360°	020°	025°	030°	040°	050°	050°
	.3	.3	.4	.3	.3	.3
030°	045°	060°	040°	045°	050°	060°
	.3	.3	.6	.5	.8	.7
060°	060°	060°	060°	060°	065°	065°
	.9	.9	.8	.6	.5	.6
090°	090°	090°	085°	085°	085°	085°
	.9	.9	.8	.8	.6	.6
120°	120°	115°	110°	110°	105°	100°
	.8	.7	.7	.6	.7	.6
150°	135°	140°	120°	130°	120°	110°
	.6	.6	.6	.6	.5	.5
180°	165°	160°	155°	140°	130°	115°
	.6	.3	.2	.5	.5	.3

AUGUSTA BAY POINT 2:

Period (sec)	6	8	10	12	14	16
Deep Water Direction	Shallow Water Direction and Height Ratio					
360°	005°	010°	015°	020°	030°	030°
	.4	.6	.7	.8	.5	.4
030°	030°	030°	030°	035°	045°	055°
	1.0	.9	.8	.7	.6	.5
060°	060°	060°	060°	060°	065°	065°
	1.0	1.0	.9	.9	.9	.9
090°	090°	090°	090°	090°	090°	090°
	1.0	1.0	.9	.9	.8	.8
120°	120°	120°	120°	120°	115°	115°
	1.0	.9	.9	.9	.8	.7
150°	150°	150°	150°	145°	145°	140°
	.9	.9	.9	.8	.8	.8
180°	180°	175°	170°	165°	160°	150°
	.6	.5	.6	.6	.6	.6

Situation specific shallow water wave conditions resulting from deep water wave propagation are given in Table 3-1 while the seasonal climatology of wave conditions in the harbor resulting from the propagation of deep water waves into the harbor are given in Table 3-2. If the actual or forecast deep water wave conditions are known, the expected conditions at the two specified harbor areas can be determined from Table 3-1. The mean duration of the condition, based on the shallow water wave heights, can be obtained from Table 3-2.

Interpretation of the information from Tables 3-1 and 3-2 provide guidance on the local wave conditions expected tomorrow at the various harbor points. The duration values are mean values for the specified height range and season. Knowledge of the current synoptic pattern and forecast/expected duration should be used when available.

Example: Use of Tables 3-1 and 3-2.

The forecast for wave conditions tomorrow (winter case) outside the harbor are:

9 feet, 12 seconds, from 090°

Expected shallow water conditions and duration:

	Point 1	Point 2
height	7 feet	8 feet
period	12 seconds	12 seconds
direction	from 085°	from 090°
duration	14 hours	10 hours

Possible applications to small boat operations are; selection of the tending ships anchorage point and/or areas of small boat work. The condition duration information provides insight as to how long before a change can be expected. The local wave direction information could be of use in selecting anchorage configuration and related small boat operations.

Table 3-2. Shallow water climatology as determined from deep water wave propagation. Percent occurrence, average duration or persistence, and wave period of maximum energy for wave height ranges of greater than 3.3 feet and greater than 6.6 feet by climatological season.

AUGUSTA POINT 1:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	30	29	8	20
Average Duration (hrs)	14	17	11	16
Period Max Energy(sec)	10	10	10	8
>6.6 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	13	10	2	5
Average Duration (hrs)	14	11	8	8
Period Max Energy(sec)	12	11	10	10

AUGUSTA POINT 2:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	29	22	9	15
Average Duration (hrs)	13	11	15	14
Period Max Energy(sec)	10	10	10	10
>6.6 feet	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	12	9	2	6
Average Duration (hrs)	10	14	11	7
Period Max Energy(sec)	12	11	10	12

Local wind wave conditions are provided in Table 3-3 for Augusta Bay point 2. The specified fetch lengths are specifically for point 2. The time to reach the fetch limited height assumes an initial flat ocean. With a pre-existing wave height, the times are shorter.

Table 3-3. Augusta Bay near point 2. Local wind waves for fetch limited conditions related to point 2 (based on JONSWAP model).

<u>Format:</u> height (feet)/period (seconds)
time (hours) to reach fetch limited height

Direction and Fetch Length (n mi) \ Local Wind Speed (kt)	18	24	30	36	42
SW 3 n mi	<2 ft	<2 ft	2/3 1	2/3 1	2-3/3 1
S 13 n mi	<2 ft	<2 ft	2/3 1	2-3/3 1	3/3 1

<u>Example: Small boat wave forecasts</u> (based on the assumption that swell is not a limiting condition).

<u>Forecast for Tomorrow:</u>

<u>Time</u>	<u>Wind (Forecast)</u>	<u>Waves (Table 3-3)</u>
prior to 0700 LST	light and variable	< 1 ft
0700 to 1200	SW 8-10 kt	< 2 ft
1200 to 1500	SW 22-26 kt	< 2 ft
1500 to 2000	SW 28-32 kt	2 ft at 3 sec by 1600
2000 to 2200	SW 14-18 kt	< 2 ft

<u>Interpretation:</u> Assuming that the limiting factor is waves greater than 2 feet, small boat operations would be marginal by 1300 and remain so until after 2000. Safe conditions would exist by 2100.

Combined wave heights are computed by finding the square root of the sum of the squares of the wind wave and swell heights. For example, if the wind waves were 3 ft and the swell 8 ft the combined height would be about 8.5 ft.

$$\sqrt{3^2 + 8^2} = \sqrt{9 + 64} = \sqrt{73} \approx 8.5$$

Note that the increased height is relatively small. Even if the two wave types were of equal height the combined heights are only 1.4 times the equal height. In cases where one or the other heights are twice that of the other, the combined height will only increase over the larger of the two by 1.12 times (10 ft swell and 5 ft wind wave combined results in 11.2 ft height).

3.6.3 Wave data uses and considerations

Local wind waves build up quite rapidly and also decrease rapidly when winds subside. The period and therefore length of wind waves is generally short relative to the period and length of waves propagated into the harbor (see Appendix A). The shorter period and length result in wind waves being characterized by choppy conditions. When wind waves are superimposed on deep water waves propagated into shallow water, the waves can become quite complex and confused. Under such conditions, when more than one source of waves is influencing a location, tending or joint operations can be hazardous even if the individual wave train heights are not significantly high. Vessels of various lengths may respond in different motions to the different wave lengths present. The information on wave periods, provided in various tables, should be considered when forecasts are made for joint operations of different length vessels.

3.7 Protective and Mitigating Measures

3.7.1 Moving to new anchorage

According to local authorities, when strong northeast to southeast winds are forecast for Augusta Bay, it is wise to depart the anchorage and move northward through the Strait of Messina and anchor along the north coast of Sicily near Messina, at Palermo or in the Gulf of Castellammare.

3.7.2 Sortie/remain in port.

Experienced mariners advise leaving the anchorage and heading for open sea when strong winds from northeast clockwise through southeast are forecast. If this course of action is chosen, moving northward through the Strait of Messina to the protected waters north of the coasts of Sicily or the Italian Peninsula could afford some protection from high wind and waves.

Likewise, if strong winds from the west quadrant -- especially from the northwest -- are forecast, it is wise to leave the inner harbor anchorage and head for open sea.

If a decision is made to stay in port, precautions should be taken. If at anchor, two or more anchors should be deployed to minimize anchor dragging in the soft mud bottom. If alongside a pier, lines should be doubled, particularly if the forecast winds will blow perpendicular to the ship's axis and tend to force the vessel off its mooring. Small boats should be firmly secured. Routine operations may be curtailed.

3.8 Local Indicators of Hazardous Weather Conditions

The environmental conditions which pose the greatest threat to harbor operations at Augusta Bay are strong winds and high waves from the east quadrant, and strong winds from the west quadrant.

Easterly Wind/Waves - Since strong winds from the east quadrant are caused by a steep north-south pressure gradient, one indicator of a potential Gregale event would be the forecast of a synoptic situation which includes a building high to the north while a low pressure center is forecast to intensify over the Ionian Sea or the North African region of Tunisia/Libya, or transit eastward south of Sicily. A persistent strong wind condition caused by a stationary or slow-moving situation may last for up to 5 days. Winds caused by a transient low pressure system will normally last for about 1-2 days. High waves will persist for about 24 hours after the generating winds diminish.

Etesian winds in the eastern Mediterranean or Aegean Seas can produce 8-12 ft (2.5-3.5 m) westerly moving swell that will reach the east coast of Sicily in 4-8 hours. Maximum occurrence is in August.

Strong winds and hot, muggy weather accompanying a Scirocco are often preceded by cumuliform clouds forming and staying over Mt. Etna (35 n mi north-northwest of the Port) during southeasterly flow conditions over eastern Sicily.

Westerly Wind - A strong or intensifying low pressure system transiting the area north of Sicily would likely produce strong westerly winds at Augusta Bay. Transient lows should be monitored closely, especially during late winter and early spring since the probability of strong Ponente winds is greatest in the month of March.

TABLE 3-4. Potential problem situations at Port of Augusta - ALL SEASONS

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
1. Anchored - inner harbor Winter Spring Summer Autumn	a. Easterly wind/sea - Can be caused by "Gregale" or "Scirocco". May produce 23-26 ft (7-8 m) seas in outer harbor. Strongest in winter, unlikely in summer. "Etesian winds over Ageanen or eastern Mediterranean Sea can cause 8-12 ft (2.5 - 3.5 m) swell off eastern Sicily, maximum occurrence in August.	a. The inner harbor, Porto Megarese, is exposed to the brunt of winds from the east quadrant, but is protected by breakwaters from significant ocean waves. Vessels are advised to leave the port for open sea if high winds from the east quadrant are forecast. Shelter can be found north of the Strait of Messina off the north coast of Sicily or the west coast of Italy. Protected anchorage may be found at Palermo, or the Gulf of Castellammare on Sicily's north coast. Vessels remaining at anchor at Augusta should use 2 anchors and be aware of possible anchor dragging. Small craft should be well secured.	a. Strong winds with an easterly component result when a building high pressure cell over central Europe coincides with an intensifying low pressure system over North Africa or the Ionian Sea (late autumn, winter, and early spring). Easterly winds associated with a Scirocco event are often preceded by cumuliform clouds staying over the summit of Mount Etna (35 n mi north-northwest of Augusta Bay). During summer an "Etesian" over the Aegean Sea will cause easterly swell at Augusta Bay 4-8 hours after generation.
Winter Strong Spring Rare Summer Autumn	b. Westerly wind - Strong winds from southwest through northwest caused by low pressure north of Sicily. Can produce gusts to 65 kts in Port. Maximum frequency in March, when events can last 2-3 days.	b. Due to the possibility of dragging anchors, vessels are advised to leave the port for open sea if strong westerly winds are forecast. Staying along and close to Sicily's east coast will provide protection from seas generated by the westerly winds. Vessels remaining at anchor should use 2 anchors and be aware of possible anchor dragging due to bottom characteristics. Small craft should be well secured.	b. High winds with a westerly component result when a low pressure system moves eastward north of Sicily. Transient extratropical lows should be monitored closely to detect any strong pressure gradients which may affect the Augusta Bay area. May be called Libeccio, Ponente, or Maestrale.
Frontal Winter Spring Orographic Summer Autumn	c. Thunderstorms - Possible with passing frontal systems, and in the following cold air. Associated wind gusts and squalls to be expected. Most common late autumn early winter with transient low centers passing south of Sicily. Orographically induced in summer.	c. Thunderstorms can pose several problems to mariners, but the most significant are lightning strikes and strong, gusty winds. Since little can be done to avoid lightning strikes, vessels are limited to preventing damage by high wind. All loose gear should be secured. Small boat operations should be curtailed. Personnel exposure on weatherdecks should be minimized.	c. Thunderstorm activity can be expected when a transient low pressure system moves eastward south of Sicily. Thunderstorm activity occurs with passing cold/occluded frontal systems and in the cold, unstable air following the front. Thunderstorms are orographically induced in summer with onshore flow.
Winter Spring Summer Autumn	d. Tropical cyclone - Uncommon in the Mediterranean but when occurring, would have a maximum probability of occurrence in late summer or early autumn. Two of the three storms recorded since 1969 have occurred in September, with maximum winds of 100 kts on one occasion. High winds/ seas/storm surge possible.	d. Because of the potential for destruction, mariners should make every effort to avoid being placed in the track of a tropical cyclone. Vessels should put to sea and take evasive action at the first indication that a tropical cyclone may strike or pass close by Augusta Bay.	d. Monitor satellite images and synoptic reports for early detection of a developing tropical cyclone. Approaching tropical cyclone may be indicated by high, thin clouds in cyclonically spiralling, gradually thickening bands or by unexplained long-period swell from the southern semicircle.
Late Spring Summer Early Autumn	e. Sea breeze - Uncommon until late spring, when daily warming of land mass is sufficient to trigger breeze. Commonly occurs between 1030L and 1800L, with maximum velocities of 15-25 kts by 1530L.	e. Boating may be curtailed during a strong event.	e. Expected afternoon sea breeze from late spring through early autumn with warm temperatures. A high aloft can suppress the sea breeze mechanism.

TABLE 3-4. (Continued)

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
2. Anchored - outer harbor Winter Spring Summer Autumn	a. Easterly wind/sea - Can be caused by "Gregale" or "Scirocco". May produce 23-26 ft (7-8 m) seas in outer harbor. Strongest in winter, unlikely in summer. "Etesian winds over Ageanen or eastern Mediterranean Sea can cause 8-12 ft (2.5 - 3.5 m) swell off eastern Sicily, maximum occurrence in August.	a. Unlike the relatively protected waters of the inner harbor, the outer harbor is exposed not only to the effects of wind, but also waves. Vessels are advised to leave the anchorage for open sea if strong easterly winds/seas are forecast. Vessels can usually find shelter by moving north through the Strait of Messina and staying in the lee of the coastlines of the Italian Peninsula or northern Sicily. Protected anchorage may be found at Palermo or in the gulf of Castellammare on Sicily's north coast.	a. Strong winds with an easterly component result when a building high pressure cell over central Europe coincides with an intensifying low pressure system over North Africa or the Ionian Sea (late autumn, winter, and early spring). Easterly winds associated with a Scirocco event are often preceded by cumuliform clouds staying over the summit of Mount Etna (35 n mi north-northwest of Augusta Bay). During summer an "Etesian" over the Aegean Sea will cause easterly swell at Augusta Bay 4-6 hours after generation.
Winter Strong Spring Rare Summer Autumn	b. Westerly wind - Strong winds from southwest through northwest caused by low pressure north of Sicily. Can produce gusts to 65 kts in Port. Maximum frequency in March, when events can last 2-3 days.	b. Due to the possibility of dragging anchors, vessels are advised to leave the port for open sea if strong westerly winds are forecast. Staying along Sicily's east coast will provide protection from seas generated by the westerly winds. Vessels remaining at anchor should use 2 anchors and be aware of possible anchor dragging. Small craft should be well secured.	b. High winds with a westerly component result when a low pressure system moves eastward north of Sicily. Transient extratropical lows should be monitored closely to detect any strong pressure gradients which may affect the Augusta Bay area. May be called Libeccio, Ponente, or Maestrale.
Frontal Winter Spring Orographic Summer Autumn	c. Thunderstorms - Possible with passing frontal systems, and in the following cold air. Associated wind gusts and squalls to be expected. Most common late autumn early winter with transient low centers passing south of Sicily. Orographically induced in summer.	c. Thunderstorms can pose several problems to mariners, but the most significant are lightning strikes and strong, gusty winds. Since little can be done to avoid lightning strikes, vessels are limited to preventing damage by high wind. All loose gear should be secured. Small boat operations should be curtailed. Personnel exposure on weatherdecks should be minimized.	c. Thunderstorm activity can be expected when a transient low pressure system moves eastward south of Sicily. Thunderstorm activity occurs with passing cold/occluded frontal systems and in the cold, unstable air following the front. Thunderstorms are orographically induced in summer with onshore flow.
Winter Spring Summer Autumn	d. Tropical cyclone - Uncommon in the Mediterranean but when occurring, would have a maximum probability of occurrence in late summer or early autumn. Two of the three storms recorded since 1969 have occurred in September, with maximum winds of 100 kts on one occasion. High winds/ seas/storm surge possible.	d. Because of the potential for destruction, mariners should make every effort to avoid being placed in the track of a tropical cyclone. Vessels should put to sea and take evasive action at the first indication that a tropical cyclone may strike or pass close by Augusta Bay.	d. Monitor satellite images and synoptic reports for early detection of a developing tropical cyclone. Approaching tropical cyclone may be indicated by high, thin clouds in cyclonically spiralling, gradually thickening bands or by unexplained long-period swell from the southern semicircle.
Late Spring Summer Early Autumn	e. Sea breeze - Uncommon until late spring, when daily warming of land mass is sufficient to trigger breeze. Commonly occurs between 1030L and 1800L, with maximum velocities of 15-25 kts by 1530L.	e. Boating may be curtailed during a strong event.	e. Expected afternoon sea breeze from late spring through early autumn with warm temperatures. A high aloft can suppress the sea breeze mechanism.

TABLE 3-4. (Continued)

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
3. Moored - inner harbor Winter Spring Summer Autumn	a. Easterly wind/sea - Can be caused by "Gregale" or "Scirocco". May produce 23-26 ft (7-8 m) seas in outer harbor. Strongest in winter, unlikely in summer. "Etesian winds over Ageanen or eastern Mediterranean Sea can cause 8-12 ft (2.5 - 3.5 m) swell off eastern Sicily, maximum occurrence in August.	a. All mooring lines should be doubled, especially if the forecast wind direction is perpendicular to the axis of the vessel and would tend to force the ship off its mooring. Secure loose gear. Curtail small boat operations.	a. Strong winds with an easterly component result when a building high pressure cell over central Europe coincides with an intensifying low pressure system over North Africa or the Ionian Sea (late autumn, winter, and early spring). Easterly winds associated with a Scirocco event are often preceded by cumuliform clouds staying over the summit of Mount Etna (35 n mi north-northwest of Augusta Bay). During summer an "Etesian" over the Aegean Sea will cause easterly swell at Augusta Bay 4-8 hours after generation.
Winter Strong Spring Rare Summer Autumn	b. Westerly wind - Strong winds from southwest through northwest caused by low pressure north of Sicily. Can produce gusts to 65 kts in Port. Maximum frequency in March, when events can last 2-3 days.	b. All mooring lines should be doubled, especially if the forecast wind direction is perpendicular to the axis of the vessel and would tend to force the ship off its mooring. Secure loose gear. Curtail small boat operations.	b. High winds with a westerly component result when a low pressure system moves eastward north of Sicily. Transient extratropical lows should be monitored closely to detect any strong pressure gradients which may affect the Augusta Bay area. May be called Libeccio, Ponente, or Maestrale.
Frontal Winter Spring Orographic Summer Autumn	c. Thunderstorms - Possible with passing frontal systems, and in the following cold air. Associated wind gusts and squalls to be expected. Most common late autumn early winter with transient low centers passing south of Sicily. Orographically induced in summer.	c. Thunderstorms can pose several problems to mariners, but the most significant are lightning strikes and strong, gusty winds. Since little can be done to avoid lightning strikes, vessels are limited to preventing damage by high wind. All loose gear should be secured. Small boat operations should be curtailed. Personnel exposure on weatherdecks should be minimized.	c. Thunderstorm activity can be expected when a transient low pressure system moves eastward south of Sicily. Thunderstorm activity occurs with passing cold/occluded frontal systems and in the cold, unstable air following the front. Thunderstorms are orographically induced in summer with onshore flow.
Winter Spring Summer Autumn	d. Tropical cyclone - Uncommon in the Mediterranean but when occurring, would have a maximum probability of occurrence in late summer or early autumn. Two of the three storms recorded since 1969 have occurred in September, with maximum winds of 100 kts on one occasion. High winds/ seas/storm surge possible.	d. Because of the potential for destruction, mariners should make every effort to avoid being placed in the track of a tropical cyclone. Vessels should put to sea and take evasive action at the first indication that a tropical cyclone may strike or pass close by Augusta Bay.	d. Monitor satellite images and synoptic reports for early detection of a developing tropical cyclone. Approaching tropical cyclone may be indicated by high, thin clouds in cyclonically spiralling, gradually thickening bands or by unexplained long-period swell from the southern semicircle.
Late Spring Summer Early Autumn	e. Sea breeze - Uncommon until late spring, when daily warming of land mass is sufficient to trigger breeze. Commonly occurs between 1030L and 1800L, with maximum velocities of 15-25 kts by 1530L.	e. Boating may be curtailed during a strong event.	e. Expected afternoon sea breeze from late spring through early autumn with warm temperatures. A high aloft can suppress the sea breeze mechanism.

TABLE 3-4. (Continued)

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
4. Arriving/departing harbor Winter Spring Summer Autumn	a. Easterly wind/sea - Can be caused by "Gregale" or "Scirocco". May produce 23-26 ft (7-8 m) seas in outer harbor. Strongest in winter, unlikely in summer. "Etesian winds over Ageanen or eastern Mediterranean Sea can cause 8-12 ft (2.5 - 3.5 m) swell off eastern Sicily, maximum occurrence in August.	a. Vessels approaching Augusta Bay should remain at sea if strong winds are occurring or are forecast for the harbor. Vessels scheduled to leave the harbor should arrange to depart prior to the onset of strong winds. All vessels should be alert for enhanced currents outside the harbor due to the effects of wind.	a. Strong winds with an easterly component result when a building high pressure cell over central Europe coincides with an intensifying low pressure system over North Africa or the Ionian Sea (late autumn, winter, and early spring). Easterly winds associated with a Scirocco event are often preceded by cumuliform clouds staying over the summit of Mount Etna (35 n mi north-northwest of Augusta Bay). During summer an "Etesian" over the Aegean Sea will cause easterly swell at Augusta Bay 4-6 hours after generation.
Winter Strong Spring Rare Summer Autumn	b. Westerly wind - Strong winds from southwest through northwest caused by low pressure north of Sicily. Can produce gusts to 65 kts in Port. Maximum frequency in March, when events can last 2-3 days.	b. Vessels approaching Augusta Bay should remain at sea if strong winds are occurring or are forecast for the harbor. Vessels scheduled to leave the harbor should arrange to depart prior to the onset of strong winds.	b. High winds with a westerly component result when a low pressure system moves eastward north of Sicily. Transient extratropical lows should be monitored closely to detect any strong pressure gradients which may affect the Augusta Bay area. May be called Libeccio, Ponente, or Maestrale.
Frontal Winter Spring Orographic Summer Autumn	c. Thunderstorms - Possible with passing frontal systems, and in the following cold air. Associated wind gusts and squalls to be expected. Most common late autumn early winter with transient low centers passing south of Sicily. Orographically induced in summer.	c. Thunderstorms can pose several problems to mariners, but the most significant are lightning strikes and strong, gusty winds. Since little can be done to avoid lightning strikes, vessels are limited to preventing damage by high wind. All loose gear should be secured. Small boat operations should be curtailed. Personnel exposure on weatherdecks should be minimized.	c. Thunderstorm activity can be expected when a transient low pressure system moves eastward south of Sicily. Thunderstorm activity occurs with passing cold/occluded frontal systems and in the cold, unstable air following the front. Thunderstorms are orographically induced in summer with onshore flow.
Winter Spring Summer Autumn	d. Tropical cyclone - Uncommon in the Mediterranean but when occurring, would have a maximum probability of occurrence in late summer or early autumn. Two of the three storms recorded since 1969 have occurred in September, with maximum winds of 100 kts on one occasion. High winds/ seas/storm surge possible.	d. Because of the potential for destruction, mariners should make every effort to avoid being placed in the track of a tropical cyclone. Vessels should put to sea and take evasive action at the first indication that a tropical cyclone may strike or pass close by Augusta Bay.	d. Monitor satellite images and synoptic reports for early detection of a developing tropical cyclone. Approaching tropical cyclone may be indicated by high, thin clouds in cyclonically spiralling, gradually thickening bands or by unexplained long-period swell from the southern semicircle.
Late Spring Summer Early Autumn	e. Sea breeze - Uncommon until late spring, when daily warming of land mass is sufficient to trigger breeze. Commonly occurs between 1030L and 1800L, with maximum velocities of 15-25 kts by 1530L.	e. Schedule arrival/departure during early morning to avoid afternoon winds.	e. Expected afternoon sea breeze from late spring through early autumn with warm temperatures. A high aloft can suppress the sea breeze mechanism.

TABLE 3-4. (Continued)

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
5. Small boat operations Winter Spring Summer Autumn	a. Easterly wind/sea - Can be caused by "Gregale" or "Scirocco". May produce 23-26 ft (7-8 m) seas in outer harbor. Strongest in winter, unlikely in summer. "Etesian winds over Ageanen or eastern Mediterranean Sea can cause 8-12 ft (2.5 - 3.5 m) swell off eastern Sicily, maximum occurrence in August.	a. Small boat operations should be curtailed if winds increase to dangerous velocities.	a. Strong winds with an easterly component result when a building high pressure cell over central Europe coincides with an intensifying low pressure system over North Africa or the Ionian Sea (late autumn, winter, and early spring). Easterly winds associated with a Scirocco event are often preceded by cumuliform clouds staying over the summit of Mount Etna (35 n mi north-northwest of Augusta Bay). During summer an "Etesian" over the Aegean Sea will cause easterly swell at Augusta Bay 4-8 hours after generation.
Winter Strong Spring Rare Summer Autumn	b. Westerly wind - Strong winds from southwest through northwest caused by low pressure north of Sicily. Can produce gusts to 65 kts in Port. Maximum frequency in March, when events can last 2-3 days.	b. Small boat operations should be curtailed if winds increase to dangerous velocities.	b. High winds with a westerly component result when a low pressure system moves eastward north of Sicily. Transient extratropical lows should be monitored closely to detect any strong pressure gradients which may affect the Augusta Bay area. May be called Libeccio, Ponente, or Maestrale.
Frontal Winter Spring Orographic Summer Autumn	c. Thunderstorms - Possible with passing frontal systems, and in the following cold air. Associated wind gusts and squalls to be expected. Most common late autumn early winter with transient low centers passing south of Sicily. Orographically induced in summer.	c. Small boats should be operated with extreme caution, and secured at the first indication of lightning or strong winds.	c. Thunderstorm activity can be expected when a transient low pressure system moves eastward south of Sicily. Thunderstorm activity occurs with passing cold/occluded frontal systems and in the cold, unstable air following the front. Thunderstorms are orographically induced in summer with onshore flow.
Winter Spring Summer Autumn	d. Tropical cyclone - Uncommon in the Mediterranean but when occurring, would have a maximum probability of occurrence in late summer or early autumn. Two of the three storms recorded since 1969 have occurred in September, with maximum winds of 100 kts on one occasion. High winds/ seas/storm surge possible.	d. All small boat operations should cease at the approach of the tropical cyclone. Small craft should be hoisted out of the water and secured on deck or, in the case of shore-based boats, well above the high tide line.	d. Monitor satellite images and synoptic reports for early detection of a developing tropical cyclone. Approaching tropical cyclone may be indicated by high, thin clouds in cyclonically spiralling, gradually thickening bands or by unexplained long-period swell from the southern semicircle.
Late Spring Summer Early Autumn	e. Sea breeze - Uncommon until late spring, when daily warming of land mass is sufficient to trigger breeze. Commonly occurs between 1030L and 1800L, with maximum velocities of 15-25 kts by 1530L.	e. Small boat operations should be curtailed if winds increase to dangerous velocities.	e. Expected afternoon sea breeze from late spring through early autumn with warm temperatures. A high aloft can suppress the sea breeze mechanism.

REFERENCES

Hydrographic Department, 1963: Mediterranean Pilot, Volume I. Published by the Hydrographic Department, under the authority of the Lords Commissioners of the Admiralty, London.

U. S. Navy, 1983: Fleet Directory for Augusta, Sicily, Italy (FOUO).

PORT VISIT INFORMATION

JUNE 1985. NEPRF meteorologists R. Fett and R. Picard met with Port Captain CDR Bursi and Chief Pilot Mr. Giannossi to obtain much of the information included in this port evaluation.

APPENDIX A

General Purpose Oceanographic Information

This section provides general information on wave forecasting and wave climatology as used in this study. The forecasting material is not harbor specific. The material in paragraphs A.1 and A.2 was extracted from H.O. Pub. No. 603, Practical Methods for Observing and Forecasting Ocean Waves (Pierson, Neumann, and James, 1955). The information on fully arisen wave conditions (A.3) and wave conditions within the fetch region (A.4) is based on the JONSWAP model. This model was developed from measurements of wind wave growth over the North Sea in 1973. The JONSWAP model is considered more appropriate for an enclosed sea where residual wave activity is minimal and the onset and end of locally forced wind events occur rapidly (Thornton, 1986), and where waves are fetch limited and growing (Hasselmann, et al., 1976). Enclosed sea, rapid onset/subsiding local winds, and fetch limited waves are more representative of the Mediterranean waves and winds than the conditions of the North Atlantic from which data was used for the Pierson and Moskowitz (P-M) Spectra (Neumann and Pierson 1966). The P-M model refined the original spectra of H.O. 603, which over developed wave heights.

The primary difference in the results of the JONSWAP and P-M models is that it takes the JONSWAP model longer to reach a given height or fully developed seas. In part this reflects the different starting wave conditions. Because the propagation of waves from surrounding areas into semi-enclosed seas, bays, harbors, etc. is limited, there is little residual wave action following periods of locally light/calm winds and the sea surface is nearly flat. A local wind developed wave growth is therefore slower than wave growth in the open ocean where some residual wave action is generally always

present. This slower wave development is a built in bias in the formulation of the JONSWAP model which is based on data collected in an enclosed sea.

A.1 Definitions

Waves that are being generated by local winds are called "SEA". Waves that have traveled out of the generating area are known as "SWELL". Seas are chaotic in period, height and direction while swell approaches a simple sine wave pattern as its distance from the generating area increases. An in-between state exists for a few hundred miles outside the generating area and is a condition that reflects parts of both of the above definitions. In the Mediterranean area, because its fetches and open sea expanses are limited, SEA or IN- BETWEEN conditions will prevail. The "SIGNIFICANT WAVE HEIGHT" is defined as the average value of the heights of the one-third highest waves. PERIOD and WAVE LENGTH refer to the time between passage of, and distances between, two successive crests on the sea surface. The FREQUENCY is the reciprocal of the period ($f = 1/T$) therefore as the period increases the frequency decreases. Waves result from the transfer of energy from the wind to the sea surface. The area over which the wind blows is known as the FETCH, and the length of time that the wind has blown is the DURATION. The characteristics of waves (height, length, and period) depend on the duration, fetch, and velocity of the wind. There is a continuous generation of small short waves from the time the wind starts until it stops. With continual transfer of energy from the wind to the sea surface the waves grow with the older waves leading the growth and spreading the energy over a greater range of frequencies. Throughout the growth cycle a SPECTRUM of ocean waves is being developed.

A.2 Wave Spectrum

Wave characteristics are best described by means of their range of frequencies and directions or their spectrum and the shape of the spectrum. If the spectrum of the waves covers a wide range of frequencies and directions (known as short-crested conditions), SEA conditions prevail. If the spectrum covers a narrow range of frequencies and directions (long crested conditions), SWELL conditions prevail. The wave spectrum depends on the duration of the wind, length of the fetch, and on the wind velocity. At a given wind speed and a given state of wave development, each spectrum has a band of frequencies where most of the total energy is concentrated. As the wind speed increases the range of significant frequencies extends more and more toward lower frequencies (longer periods). The frequency of maximum energy is given in equation 1.1 where v is the wind speed in knots.

$$f_{max} = \frac{2.476}{v} \qquad (1.1)$$

The wave energy, being a function of height squared, increases rapidly as the wind speed increases and the maximum energy band shifts to lower frequencies. This results in the new developing smaller waves (higher frequencies) becoming less significant in the energy spectrum as well as to the observer. As larger waves develop an observer will pay less and less attention to the small waves. At the low frequency (high period) end the energy drops off rapidly, the longest waves are relatively low and extremely flat, and therefore also masked by the high energy frequencies. The result is that 5% of the upper frequencies and 3% of the lower frequencies can be cut-off and only the remaining

frequencies are considered as the "significant part of the wave spectrum". The resulting range of significant frequencies or periods are used in defining a fully arisen sea. For a fully arisen sea the approximate average period for a given wind speed can be determined from equation (1.2).

$$\bar{T} = 0.285v \tag{1.2}$$

Where v is wind speed in knots and T is period in seconds. The approximate average wave length in a fully arisen sea is given by equation (1.3).

$$\bar{L} = 3.41\ \bar{T}^2 \tag{1.3}$$

Where $\bar{L}$ is average wave length in feet and $\bar{T}$ is average period in seconds.

The approximate average wave length of a fully arisen sea can also be expressed as:

$$\bar{L} = .67\text{"L"} \tag{1.4}$$

where "L" = $5.12T^2$, the wave length for the classic sine wave.

A.3 Fully Arisen Sea Conditions

For each wind speed there are minimum fetch (n mi) and duration (hr) values required for a fully arisen sea to exist. Table A-1 lists minimum fetch and duration values for selected wind speeds, values of significant wave (average of the highest 1/3 waves) period and height, and wave length of the average wave during developing and fully arisen seas. The minimum duration time assumes a start from a flat sea. When pre-existing

lower waves exist the time to fetch limited height will be shorter. Therefore the table duration time represents the maximum duration required.

Table A-1. Fully Arisen Deep Water Sea Conditions Based on the JONSWAP Model.

Wind Speed (kt)	Minimum Fetch/Duration (n mi)	(hrs)	Sig Wave (H1/3) Period/Height (sec)	(ft)	Wave Length (ft)[1,2] Developing/Fully /Arisen L X (.5)	/L X (.67)
10	28 /	4	4 /	2	41 /	55
15	55 /	6	6 /	4	92 /	123
20	110 /	8	8 /	8	164 /	220
25	160 /	11	9 /	12	208 /	278
30	210 /	13	11 /	16	310 /	415
35	310 /	15	13 /	22	433 /	580
40	410 /	17	15 /	30	576 /	772

NOTES:

[1] Depths throughout fetch and travel zone must be greater than 1/2 the wave length, otherwise shoaling and refraction take place and the deep water characteristics of waves are modified.

[2] For the classic sine wave the wave length (L) equals 5.12 times the period (T) squared ($L = 5.12T^2$). As waves develop and mature to fully developed waves and then propagate out of the fetch area as swell their wave lengths approach the classic sine wave length. Therefore the wave lengths of developing waves are less than those of fully developed waves which in turn are less than the length of the resulting swell. The factor of .5 (developing) and .67 (fully developed) reflect this relationship.

A.4 Wave Conditions Within The Fetch Region

Waves produced by local winds are referred to as SEA. In harbors the local sea or wind waves may create hazardous conditions for certain operations. Generally within harbors the fetch lengths will be short and therefore the growth of local wind waves will be fetch limited. This implies that there are locally determined upper limits of wave height and period for each wind velocity. Significant changes in speed or direction will result in generation of a new wave group with a new set of height and period limits. Once a fetch limited sea reaches its upper limits no further growth will occur unless the wind speed increases.

Table A-2 provides upper limits of period and height for given wind speeds over some selected fetch lengths. The duration in hours required to reach these upper limits (assuming a start from calm and flat sea conditions) is also provided for each combination of fetch length and wind speed. Some possible uses of Table A-2 information are:

1) If the only waves in the area are locally generated wind waves, the Table can be used to forecast the upper limit of sea conditions for combinations of given wind speeds and fetch length.

2) If deep water swell is influencing the local area in addition to locally generated wind waves, then the Table can be used to determine the wind waves that will combine with the swell. Shallow water swell conditions are influenced by local bathymetry (refraction and shoaling) and will be addressed in each specific harbor study.

3) Given a wind speed over a known fetch length the maximum significant wave conditions and time needed to reach this condition can be determined.

Table A-2. Fetch Limited Wind Wave Conditions and Time Required to Reach These Limits (Based on JONSWAP Model). Enter the table with wind speed and fetch length to determine the significant wave height and period, and time duration needed for wind waves to reach these limiting factors. All of the fetch/speed combinations are fetch limited except the 100 n mi fetch and 18 kt speed.

Format: height (feet)/period (seconds)
duration required (hours)

Fetch Length (n mi) \ Wind Speed (kt)	18	24	30	36	42
10	2/3-4 1-2	3/3-4 2	3-4/4 2	4/4-5 1-2	5/5 1-2
20	3/4-5 2-3	4/4-5 3	5/5 3	6/5-6 3-4	7/5-6 3
30	3-4/5 3	5/5-6 4	6/6 3-4	7/6 3-4	8/6-7 3
40	4-5/5-6 4-5	5/6 4	6-7/6-7 4	8/7 4	9-10/7-8 3-4
100	5/6-7[1] 5-6	9/8 8	11/9 7	13/9 7	15-16/9-10 7

[1] 18 kt winds are not fetch limited over a 100 n mi fetch.

An example of expected wave conditions based on Table A-2 follows:

WIND FORECAST OR CONDITION

An offshore wind of about 24 kt with a fetch limit of 20 n mi (ship is 20 n mi from the coast) is forecast or has been occurring.

SEA FORECAST OR CONDITION

From Table A-2: If the wind condition is forecast to last, or has been occurring, for at least 3 hours:

Expect sea conditions of 4 feet at 4-5 second period to develop or exist. If the condition lasts less than 3 hours the seas will be lower. If the condition lasts beyond 3 hours the sea will not grow beyond that developed at the end of about 3 hours unless there is an increase in wind speed or a change in the direction that results in a longer fetch.

A.5 Wave Climatology

The wave climatology used in these harbor studies is based on 11 years of Mediterranean SOWM output. The MED-SOWM is discussed in Volume II of the U.S. Naval Oceanography Command Numerical Environmental Products Manual (1986). A deep water MED-SOWM grid point was selected as representative of the deep water wave conditions outside each harbor. The deep water waves were then propagated into the shallow water areas. Using linear wave theory and wave refraction computations the shallow water climatology was derived from the modified deep water wave conditions. This climatology does not include the local wind generated seas. This omission, by design, is accounted for by removing all wave data for periods less than 6 seconds in the climatology. These shorter period waves are typically dominated by locally generated wind waves.

A.6 Propagation of Deep Water Swell Into Shallow Water Areas

When deep water swell moves into shallow water the wave patterns are modified, i.e., the wave heights and directions typically change, but the wave period remains constant. Several changes may take place including shoaling as the wave feels the ocean bottom, refraction as the wave crest adjusts to the bathymetry pattern, changing so that the crest becomes more parallel to the bathymetry contours, friction with the bottom sediments, interaction with currents, and adjustments caused by water temperature gradients. In this work, only shoaling and refraction effects are considered. Consideration of the other factors are beyond the resources available for this study and, furthermore, they are considered less significant in the harbors of this study than the refraction and shoaling factors.

To determine the conditions of the deep water waves in the shallow water areas the deep water

conditions were first obtained from the Navy's operational MED-SOWM wave model. The bathymetry for the harbor/area of interest was extracted from available charts and digitized for computer use. Figure A-1 is a sample plot of bathymetry as used in this project. A ray path refraction/shoaling program was run for selected combinations of deep water wave direction and period. The selection was based on the near deep water wave climatology and harbor exposure. Each study area requires a number of ray path computations. Typically there are 3 or 4 directions (at 30° increments) and 5 or 6 periods (at 2 second intervals) of concern for each area of study. This results in 15 to 24 plots per area/harbor. To reduce this to a manageable format for quick reference, specific locations within each study area were selected and the information was summarized and is presented in the specific harbor studies in tabular form.

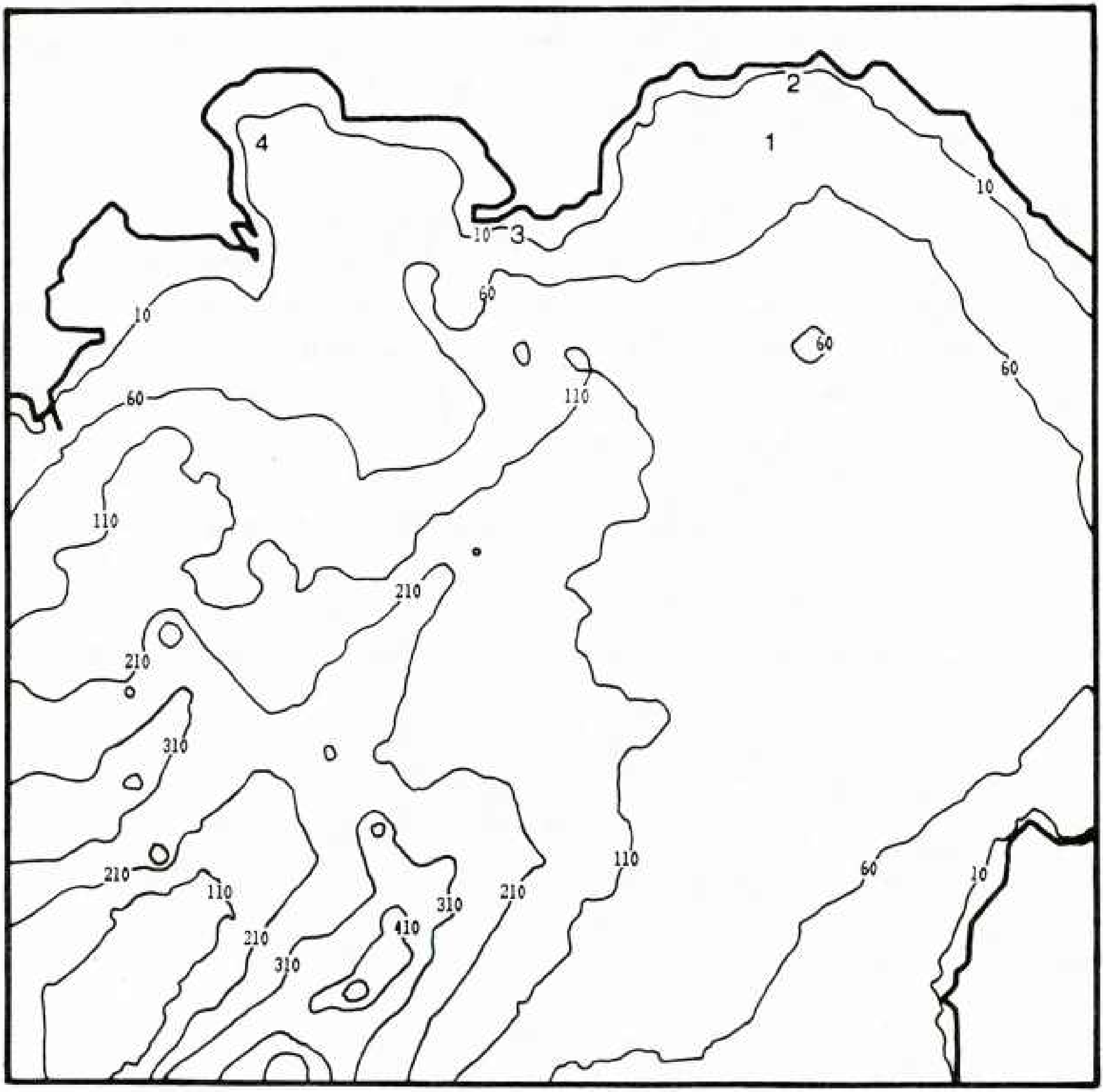

Figure A-1. Example plot of bathymetry (Naples harbor) as used in this project. For plotting purposes only, contours are at 50 fathom intervals from an initial 10 fathoms to 110 fathoms, and at 100 fathom intervals thereafter. The larger size numbers identify specific anchorage areas addressed in the harbor study.

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